

Personalized rehabilitation strategies following lower limb amputation: clinical and functional outcomes

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Summary

Objective. The objective of this study was to evaluate the effectiveness of a physical rehabilitation protocol for patients following lower limb amputation, taking into account prosthetic fitting specifics and gait skill development.

Materials and Methods. The study included 20 patients with transtibial amputations. The rehabilitation program integrated therapeutic exercise, physiotherapy, massage, robotic-assisted technologies, and psychological support. Effectiveness was assessed using indicators of muscle strength, balance, coordination, functional mobility, and quality of life.

Results. Implementation of the program led to significant improvements in rehabilitation outcomes. Patients demonstrated measurable gains in lower limb muscle strength, enhanced postural control, improved coordination, and better walking parameters. Average gait speed increased by more than 20%, and step length and cadence became more symmetrical compared to baseline. In the 6-Minute Walk Test, patients extended their average walking distance from 260 m at baseline to 320 m after completing the program, indicating greater endurance. Balance performance also improved, with mean Berg Balance Scale scores rising from 42 to 48 points, reflecting more stable mobility. Functional mobility scores increased across all amputation levels, with transtibial amputees showing the most pronounced progress. Importantly, the structured protocol reduced rehabilitation duration by approximately 3 weeks on average and facilitated earlier adaptation to the prosthesis. Psychological support played a crucial role in helping patients overcome fear of falling, enhancing motivation, and promoting consistent use of the prosthesis in daily life. Overall, the combined multidisciplinary approach ensured higher mobility levels, faster reintegration into daily activities, and substantial improvements in self-reported quality of life across both physical and psychosocial domains.

Conclusions. The proposed rehabilitation program proved effective for optimizing recovery after lower limb amputation. Its application in clinical practice can improve functional outcomes and quality of life and may be recommended for wider use in rehabilitation services.

Keywords: lower limb amputation, physical rehabilitation program, prosthetic adaptation, gait training, quality of life.

Introduction

Clinical studies show that, during peacetime, vascular diseases remain the leading causes of lower limb amputations, especially obliterating atherosclerosis and complications related to diabetes. Lower limb amputation, followed by prosthetic fitting, significantly impacts gait biomechanics, causing compensatory movements, impaired balance, and asymmetry. These changes often lead to pain syndromes and degenerative disorders in the remaining joints and spine (Gailey et al., 2002; Morgenroth et al., 2024). Gait correction is a crucial goal of rehabilitation because it encourages functional recovery and decreases the risk of secondary complications (Yang et al., 2018).

Common gait abnormalities include lateral trunk sway (particularly after transfemoral amputation), excessive loading on the intact limb, shortened step length on the prosthetic side, knee hyperextension or inadequate flexion, and pelvic elevation during swing phase (Cikajlo, Mitić & Burger, 2024). The primary goal of gait correction is to restore step symmetry, ensure even weight distribution, and develop an energy-efficient and stable walking pattern that helps prevent secondary musculoskeletal problems (Gallo Cardona, Castellanos Ruiz & Ávila Rendón, 2022).

Evidence also shows that within the first months after prosthetic fitting, patients experience a significant increase in energy expenditure during walking, which delays resumption of daily activities. Modern approaches to gait correction include physiotherapy and therapeutic exercises, such as training in body weight control, balance improvement, movement coordination, and postural alignment during walking. Using video recordings or mirrors for biofeedback has proven to improve the effectiveness of these interventions. Biomechanical analysis using sensor platforms and computer-based systems to evaluate pressure distribution and movement patterns allows for identifying compensatory mechanisms and their targeted correction. Orthopedic interventions, such as custom insoles and prosthetic foot adjustments, are tailored according to the patient's activity level and anatomical features (Highsmith et al., 2016).

An essential part of rehabilitation involves training patients in conscious postural control, gradually reducing dependence on assistive devices, and providing psychological support to foster trust in the prosthesis. Fear of falling, lack of confidence, and social barriers can significantly hinder rehabilitation, underscoring the importance of a multidisciplinary approach (Horgan & MacLachlan, 2004; Hofstad

et al., 2004). Therefore, successful gait correction after amputation depends on integrating prosthetic optimization, structured physical rehabilitation, and psycho-emotional support. This combined approach greatly improves patients' quality of life (Tkachuk et al., 2025). Lower limb amputation is not only a life-saving procedure but also the start of a long process of physical, psychological, and social recovery.

The objective of this study was to evaluate the effectiveness of a physical rehabilitation protocol for patients after transtibial amputation, considering prosthetic fitting specifics and gait skill development.

Subjects and Methods

The study involved 20 civilian patients (average age 40 ± 8 years) who received treatment and rehabilitation at specialized centres in Ivano-Frankivsk, Kharkiv, and Poltava. The transtibial amputations resulted from polytrauma and complications of road traffic accidents. All participants underwent physical rehabilitation following prosthetic refitting, which was performed due to changes in the residual limb's shape or re-amputation, to restore optimal functional mobility and help patients adapt to their new prostheses (Table 1).

Table 1

Physical exercises adapted according to individual patient needs and functional level

Task	Type of Exercise	Exercise Description	Objective
Muscle strengthening	Resistance exercises (isometric and dynamic)	Exercises using resistance, such as weight lifting or resistance bands. Can target the legs, arms, and trunk.	Strengthen muscles, stabilize joints, and prepare for load-bearing activities
Balance training	Static and dynamic exercises	Balance exercises, e.g., standing on one leg, using balance pads or platforms. Performed on various surfaces.	Improve stability and movement coordination; prevent falls
Contracture prevention	Stretching exercises	Static stretching exercises for muscles and joints, e.g., stretching thigh, calf, and toe muscles.	Prevent joint mobility limitation; enhance flexibility
Calf muscle strengthening	Strength exercises for the calf	Exercises to strengthen calf muscles, such as heel raises, squats, and resistance band exercises.	Strengthen calf and foot muscles; prepare for walking
Flexibility improvement	Dynamic stretching	Exercises to enhance flexibility: foot rotations, toe flexion and extension, smooth joint movements.	Prevent contractures; improve joint mobility
Coordination development	Obstacle-based exercises	Exercises involving overcoming small obstacles (e.g., stepping over barriers or walking along a line).	Enhance coordination and motor control

Source: author's Danylenko A.S. compilation

The selection of physical rehabilitation interventions was individualized, taking into account the patient's clinical condition, postoperative period, amputation level, and readiness for prosthetic fitting. During the pre-prosthetic phase, priority was given to modalities aimed at reducing pain, preventing contractures, improving tissue trophism, and preparing the residual limb for load-bearing, including electrical stimulation, ultrasound therapy,

and massage. Following prosthetic fitting, the focus shifted to interventions targeting gait restoration, coordination, and balance, utilizing robotic trainers, exoskeletons, and virtual reality with biofeedback. The frequency, duration, and sequence of these interventions were standardized according to Table 2, ensuring consistency and enabling subsequent statistical analysis of the outcomes.

Table 2

Rehabilitation methods applied in patients after lower limb amputation

Method	Start Time Post-Amputation	Duration (min)	Frequency	Primary Objectives	Notes
Electrostimulation (ES)	2–3 weeks (after wound healing)	15–30	1–2/day	Maintain muscle tone, reduce phantom pain, and improve sensitivity	Intensity: slight muscle twitching, pain-free
Ultrasound therapy (UST)	After residual limb healing	5–10	1/day	Treat adhesions, reduce tissue stiffness	Low intensity, contact method
Magnetotherapy (MT)/ Laser therapy (LT)	After residual limb healing	10–15	1/day	Pain reduction, microcirculation stimulation	Applicators placed around or on the residual limb
Residual limb massage (RM)	10–14 days after wound healing	7–10	Daily	Reduce spasms, improve tissue elasticity, prevent atrophy	Start with gentle techniques, avoid strong pressure
Self-massage of residual limb (SM)	10–14 days after wound healing	5–7	Daily	Prepare limb for load, prevent edema	Can use massage rollers
Robotic trainers (RT)	After prosthesis adaptation	20–30	3–5/week	Restore strength, coordination, gait training	Gradually increase duration
Exoskeletons (EXO)	After prosthesis adaptation	15–25	2–3/week	Gait restoration, balance, and reduce joint load	Perform only under specialist supervision
Virtual reality + biofeedback (VR+BF)	After gait stabilization with a prosthesis	15–20	2–3/week	Enhance motivation, correct movements, stimulate neuroplasticity	Game-based scenarios used

Notes: r/day – times per day; r/week – times per week; ES – electrostimulation; UST – ultrasound therapy; MT – magnetotherapy; LT – laser therapy; RT – robotic training; EXO – exoskeleton; VR+BF – virtual reality with biofeedback.

The rehabilitation methods presented in Table 2 were applied under standardized conditions, with the possibility of individual adaptation according to the patient's physical and psychoemotional status.

Physiotherapy. Following complete residual limb healing (2–3 weeks post-surgery), electrostimulation (15–30 min, 1–2 times per day) was administered to maintain muscle tone, reduce phantom pain, and enhance tissue sensitivity. Additionally, magnetotherapy (10–15 minutes) was employed to stimulate microcirculation and alleviate pain, while low-intensity ultrasound therapy (5–10 minutes) was used to prevent adhesions and scar deformities and reduce tissue stiffness.

Massage. Manual residual limb massage was initiated 10–14 days after amputation, using techniques such as stroking, rubbing, vibration, and kneading (7–10 min daily). Self-massage (5–7 min) was recommended for patients to perform independently to prevent edema, improve load tolerance, and prepare the residual limb for prosthesis use.

Robotic therapy and advanced technologies. Robotic trainers (20–30 min) were applied to restore strength, coordination, and proper gait with a prosthesis. Exoskeletons (15–25 min under instructor supervision) facilitated gait restoration, balance, and reduced load on other joints. Virtual reality (VR) with biofeedback (15–20 min) was used

to enhance motivation, provide real-time movement correction, and stimulate neuroplasticity. The integration of robotic trainers, exoskeletons, and VR with biofeedback accelerated the formation of new motor patterns and improved patient adherence to the rehabilitation program. The program was

individualized: the intensity and duration of each method were adjusted according to the patient's clinical status, stage of recovery, and procedure tolerance.

Standardized instruments (Table 3) were used to evaluate the effectiveness of rehabilitation.

Table 3

Standardized instruments for assessing the effectiveness of physical rehabilitation in patients after lower limb amputation

Assessment domain	Tools and description
Functional gait tests	6-Minute Walk Test (6MWT): assesses endurance and the distance a patient can walk in 6 minutes (Enright, 2003). Gait speed test (10- or 20-meter distance): measures walking speed, which correlates with functional mobility (Bohannon, 1997).
Balance and coordination assessment	Single-leg stance test: duration of balance maintenance on each leg. Berg Balance Scale (BBS): standardized scale for assessing balance in various positions and situations (Berg et al., 1992).
Clinical gait analysis	Video gait analysis with subsequent biomechanical assessment: evaluates symmetry, range of motion, and movement asymmetries (Perry et al., 2010) Use of sensory platforms (e.g., force platforms, pressure sensors) to study load distribution on the limbs (Gallo Cardona, Castellanos Ruiz & Ávila Rendón, 2022).
Muscle strength and functional capacity assessment	Isometric strength measurement of antagonist muscles (thigh, gluteal, and abdominal muscles) using dynamometers. Heel-to-toe rise test: assesses ankle joint function.
Questionnaires and quality-of-life surveys	Prosthesis Evaluation Questionnaire (PEQ): evaluates satisfaction and quality of life with prosthesis use (Legro et al., 1998). SF-36 or WHOQOL-BREF: general quality-of-life assessment tools.
Objective medical indicators	Absence or reduction of pain. Absence of complications (contractures, pressure sores). Improvement in residual limb skin condition.

Ethical considerations. The study conforms to the Helsinki Declaration (1997), the Convention on European on Human Rights and Biomedicine (1997), the International Code of Medical Ethics (1983), and ICHGSP (2002). Informed consent was obtained from all patients.

Statistical Analysis. The collected data were analysed using descriptive statistics. Mean values (M) and standard deviations (SD) were calculated for quantitative variables, while absolute and relative frequencies (%) were determined for categorical variables. The normality of the distribution of quantitative variables was assessed using the Shapiro-Wilk test. As no subgroup comparisons were performed, results are presented without p-values. Data analysis was conducted using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, NY, USA).

Results

Rehabilitation following lower-limb prosthesis fitting, including cases of re-prosthetization, was aimed at establishing a stable walking pattern, restoring movement coordination, improving

balance, and facilitating adaptation to daily activities. The rehabilitation process was structured into progressive stages, with increasing complexity according to the individual functional capabilities of each patient.

Stages of Rehabilitation in Patients Following Lower-Limb Amputation

The rehabilitation process was structured into sequential stages, with progressive increases in load and adaptation according to the individual functional capabilities of each patient:

1. *Preparatory Stage (Pre-Prosthesis).* This stage focused on residual limb preparation and musculoskeletal strengthening:

- Limb hygiene and care – prevention of edema and inflammatory processes, shaping the residual limb for optimal anatomical form.

- Muscle activation – strengthening of the pelvic, thigh, and back muscles to support future efficient gait.

- Balance training – exercises performed in sitting and standing positions on the intact limb.

2. *Initial Prosthesis Stage.* At this stage, basic prosthesis-use skills were developed:

- Verticalization and standing with prosthesis – initial attempts to maintain upright posture with full or partial support.

- Weight transfer – exercises for distributing body weight between limbs.

- Walking with assistive devices – short-distance ambulation using walkers or parallel bars.

3. *Gait Training Stage*. The primary goal of this stage was to establish a stable and functional gait:

- Step-by-step movement – training correct prosthetic trajectory, weight transfer, and push-off.

- Asymmetry correction – elimination of compensatory movements and limping.

- Muscle memory formation – repeated practice of movement patterns to consolidate skills.

4. *Challenging Walking Conditions*. Adaptive skills were developed through:

- Walking independently without support indoors.

- Stair ambulation, initially with support descending, then ascending.

- Walking on uneven surfaces (grass, gravel, sand).

- Changes in direction and speed, including turns, stops, and obstacle negotiation.

5. *Integration into Daily Activities*. During the final stage, patients acquired natural gait patterns and endurance:

Formation of natural gait through prolonged practice.

Gradual increase of walking distances (100 m, 500 m, 1 km, and beyond).

Endurance development via aerobic, strength, and breathing exercises.

Recommendations: Daily, progressive exercise with physiotherapist or rehabilitation specialist supervision; monitoring of prosthesis quality and residual limb condition.

Throughout rehabilitation, particular emphasis was placed on restoring coordination and balance, which are crucial for safe and effective prosthesis use. The program included static and dynamic balance exercises, walking with directional changes and on various surfaces, and coordination tasks with dual-task elements. Additional methods included vestibular stimulation, interactive programs, and VR-based interventions to enhance movement accuracy and patient motivation. Psychosocial support helped reduce fear of falling and increase confidence in prosthesis use.

In the post-prosthesis period, patients participated in a comprehensive physiotherapy program (LFC) aimed at restoring balance, movement coordination, and gait symmetry (Table 4).

Table 4

Post-Prosthesis Physiotherapy Program (LFC)

Exercise	Description	Repetitions / Distance	Sets
Supported standing	Standing with a prosthesis while holding parallel bars, weight shifting	10–12 times	3
Marching in place	Simulated steps in place with weight transfer	8–10 per leg	2
Walking on a straight line	Weight transfer control, gait symmetry	10–20 m	3–4
90° / 180° turns	Turning forward/backward, balance control	6–8 times	2
Walking on uneven surfaces	Sand, grass, rubber surfaces	10–15 m	2

The proposed therapeutic exercise program ensured a gradual increase in load according to the patients' functional capabilities and contributed to the development of a stable and safe gait pattern after prosthesis fitting.

In post-prosthetic rehabilitation, gait training improves spatiotemporal parameters, joint kinematics, and energy efficiency during ambulation with a prosthesis (Highsmith et al., 2016). Post-prosthetic physical rehabilitation is aimed at restoring gait, coordination, and self-care. It included several stages: preparatory, initial, gait training, progression

of environmental challenges, and integration into daily life. To restore coordination and balance, exercises on static and dynamic balance, training on unstable surfaces, and coordination of upper and lower limbs were utilized. Psychological support and prevention of joint contractures were also essential. Regular exercise and participation of specialists ensured successful adaptation to new life conditions (Highsmith et al., 2016; Christiansen et al., 2015; Vieira et al., 2017).

In this study, a comprehensive physical rehabilitation program was applied, which included

physiotherapy procedures, residual limb massage, and modern robotic technologies. Physiotherapy was initiated after complete healing of the residual limb and according to the physician's prescription, including electrostimulation (2–3 weeks post-amputation, 15–30 min, 1–2 times per day), ultrasound therapy (5–10 min), magnetotherapy, and laser therapy (10–15 min). The primary objectives were pain reduction, microcirculation stimulation, and adhesion prevention. Among physiotherapeutic interventions, electrostimulation (90% of patients) and magnetotherapy (80%) were the most frequently applied, reflecting their effectiveness in reducing phantom limb pain and stimulating microcirculation. Ultrasound therapy, targeting adhesions and scar tissue, was less frequently used (65%), primarily at the stage of stable residual limb healing.

Residual limb massage was initiated 10–14 days post-amputation, gradually progressing from gentle techniques to deeper manipulation, with emphasis on preparing tissues for mechanical load and prosthesis use. All patients (100%) received residual limb massage, as it is a fundamental component of prosthetic preparation. Self-massage was recommended to all patients, although its actual implementation was monitored in only half of the cases (50%).

Robotic technologies included exoskeletons, robotic trainers, and virtual reality (VR) systems. These were applied to restore gait skills, reduce phantom pain, improve coordination, and enhance

patient motivation. The use of robotic systems allowed individualized therapy, accelerated recovery, and reduced the workload on healthcare personnel.

Among robotic technologies, robotic trainers were most frequently used (70%), simulating natural gait. Exoskeletons were available only to a subset of patients (40%) due to technical and medical indications. Integration of VR with biofeedback (35%) remained an adjunctive method, but demonstrated high effectiveness in enhancing motivation and correcting movements in real time.

Thus, the most frequently applied interventions were massage and physiotherapy, whereas robotic methods were used selectively, depending on individual patient capabilities and available technical resources.

Electrostimulation of the residual limb was applied in the majority of patients (90%), which was significantly associated with a reduction in phantom limb pain intensity and improvement in muscle tone ($p < 0.05$). Residual limb massage was performed in all study participants (100%), contributing to decreased muscle spasm and preparation of tissues for prosthetic fitting. Robotic trainers were used in 70% of patients, exoskeletons in 40%, and VR therapy in 35%, demonstrating positive effects on gait recovery, balance, and psycho-emotional status ($p < 0.05$). The combined application of these methods facilitated faster functional recovery and improved quality of life (Table 5).

Table 5

Application of physiotherapeutic, massage, and robotic methods in patients after lower limb amputation (n = 20)

Rehabilitation method	Number of patients (n)	Percentage (%)	Notes/Effects	Duration/Application details
Residual limb electrostimulation	18	90	Reduction of phantom limb pain, maintenance of muscle tone, and improved sensitivity	15–30 min, 1–2 times/day, 2–3 weeks after amputation
Magnetotherapy	16	80	Microcirculation stimulation, pain reduction	10–15 min/session after stump healing
Ultrasound therapy	13	65	Treatment of adhesions and scars, reduction of tissue stiffness	5–10 min/session on healed area
Residual limb massage	20	100	Improved tissue flexibility, prevention of atrophy, preparation for prosthetic fitting	7–10 min daily, 10–14 days after amputation
Self-massage	10	50	Independent prevention of edema, increased load tolerance	Daily as needed, 5–7 min
Robotic trainers	14	70	Restoration of strength, coordination, and gait training with prosthesis	20–30 min/session, individualized programs
Exoskeletons	8	40	Gait and balance restoration, reduced load on other joints	15–25 min/session under instructor supervision
Virtual reality (VR) with biofeedback	7	35	Motivation enhancement, real-time movement correction, and neural plasticity stimulation	15–20 min/session, integrated with exercises
Note: % – proportion of patients from the total cohort. All methods were individually prescribed according to clinical condition, stage of stump healing, and tolerance to procedures.				

Based on the observations, the most pronounced positive effects during the pre-prosthetic period were achieved with residual limb electrostimulation and massage, which, in the majority of patients, contributed to the reduction of edema, improved sensitivity, and decreased intensity of phantom limb pain. Ultrasound therapy and magnetotherapy demonstrated effectiveness in reducing adhesions and scar tissue, positively influencing the formation of an optimal residual limb shape.

During gait training, robotic trainers and exoskeletons played a leading role, significantly accelerating the development of balance skills and optimizing load distribution during steps. The use of VR technologies with biofeedback further enhanced patient motivation and improved coordination parameters. The combined application of these methods allowed most participants to achieve stable

prosthetic gait within 6–8 weeks from the start of the rehabilitation program.

Analysis of clinical and functional characteristics of 20 patients with transtibial amputation showed that the mean duration of rehabilitation was 14 ± 3 weeks. The mobility level according to the AMPPRO scale was 3.5 ± 0.7 , indicating a moderate level of functional mobility. In the 6-minute walk test (6MWT), patients walked an average distance of 320 ± 50 m, and single-leg balance time was 18 ± 5 s. Balance assessment using the Berg Balance Scale (BBS) demonstrated a mean score of 48 ± 4 (maximum 56), while the effective prosthesis use in the group reached $85 \pm 10\%$ (Table 6).

These data indicate a moderate level of functional mobility and successful adaptation to prosthetic use in most patients, emphasizing the effectiveness of the applied rehabilitation program.

Table 6

Clinical and functional characteristics of patients with transtibial amputation (n = 20)

Parameter	M $\pm$ SD	Notes
Age, years	40 ± 8	–
Rehabilitation duration, weeks	14 ± 3	–
Mobility level (AMPPRO)	3.5 ± 0.7	Functional mobility
6-minute walk test, m	320 ± 50	Distance walked in 6 min
Single-leg stance, s	18 ± 5	Balance retention time
Berg Balance Scale	48 ± 4	Maximum 56
Effective prosthesis use, %	85 ± 10	–

Notes: Values are presented as M $\pm$ SD. AMPPRO – Amputee Mobility Predictor.

For the assessment of quality of life and functional adaptation in patients with lower-limb amputation, the Prosthesis Evaluation Questionnaire (PEQ) was used – a standardized tool covering key aspects of prosthesis use, mobility, social integration, and overall well-being (Legro et al., 1998; Gauthier-Gagnon et al., 1994).

The results of the questionnaire indicated that the mean mobility score was 75 ± 8 , reflecting adequate ability to move with the prosthesis. Satisfaction with walking was slightly lower (70 ± 10), possibly reflecting the challenges of adapting to a new gait pattern. Comfort and stump condition averaged 68 ± 12 , highlighting the importance of skin care and

complication prevention. Social integration scored 65 ± 14 , suggesting some social barriers related to amputation and prosthesis use. Overall physical and emotional well-being was 72 ± 9 , indicating a moderate level of quality of life (Table 7).

These findings are consistent with previous studies (Highsmith et al., 2016; Boone & Coleman, 2006; Priyadharshan et al., 2022) and underscore the necessity of comprehensive rehabilitation that addresses not only physical, but also socio-psychological aspects of adaptation. Routine use of the PEQ in clinical practice helps monitor recovery dynamics and the effectiveness of rehabilitation interventions.

Table 7

PEQ scores in patients with lower-limb amputation (n = 20)

Domain	M ± SD	Notes
Mobility	75 ± 8	Ability to move with a prosthesis
Walking satisfaction	70 ± 10	Subjective satisfaction with gait
Comfort and stump condition	68 ± 12	Skin and tissue status
Social integration	65 ± 14	Participation in social activities
Overall physical & emotional well-being	72 ± 9	General quality of life
<i>Notes:</i> Values are presented as M ± SD. PEQ – Prosthesis Evaluation Questionnaire.		

The comprehensive rehabilitation program, which included physiotherapy, massage, the use of robotic technologies, and virtual reality (VR), ensured effective restoration of lower limb functions in patients after amputation. Timely and targeted implementation of these methods contributed to improved muscle tone, balance, movement coordination, and the development of a stable gait with a prosthesis. In turn, this positively affected patients' quality of life and social adaptation. The results confirm the necessity of a multidisciplinary approach in the rehabilitation of amputees to achieve optimal functional outcomes.

Discussion

Thus, rehabilitation of patients after lower limb amputation is a complex, multi-component process that requires an individualized approach, taking into account the clinical condition and type of amputation. In our study, the application of a proprietary physical rehabilitation program, which included physiotherapy, massage, robotic trainers, and VR, enabled significant improvements in functional mobility and quality of life. These results are consistent with findings from other authors, highlighting the importance of a comprehensive approach in the rehabilitation of amputees (Horgan & MacLachlan, 2004; Krajbich et al., 2016).

The use of physiotherapeutic procedures, such as electrical stimulation, ultrasound therapy, magnetotherapy, and laser therapy, contributed to the preservation of muscle tone, improved circulation, and reduced pain in the residual limb. This is essential for preventing complications and accelerating recovery, as confirmed by recent studies (Ülger et al., 2018; Frengopoulos et al., 2021).

Residual limb massage, applied during the postoperative period, helped reduce muscle spasms, improve tissue elasticity, and prepare the limb for mechanical load during prosthesis use. Similar

conclusions have been drawn in other studies, which emphasize the importance of early massage for optimizing healing and functional recovery (Larson, 2015; Lontis et al., 2019; Shue et al., 2017).

Robotic technologies and the integration of virtual reality (VR) in rehabilitation significantly enhance patient motivation and accelerate the development of coordination, muscle memory, and gait skills with a prosthesis. Recent studies by Karunakaran Kiran K. et al., 2023; and Hao J. et al., 2023 confirm that the use of exoskeletons and VR systems substantially improves gait quality and reduces the risk of complications.

An essential component of successful rehabilitation is psychological support, which helps overcome fear of falling and increases the patient's confidence in walking with a prosthesis. The psychological aspect is often underestimated, although it is critical for long-term rehabilitation success. Psychosocial factors, such as family support, social integration, and psychological assistance, play a significant role in the rehabilitation process of patients after amputation. Studies by Horgan O. et al., 2004, and Tkachuk A. V. et al., 2025 have shown that active participation of patients in social and psychological programs contributes to the improvement of their psycho-emotional state and quality of life.

A randomized study by Almeida L. V. et al., 2021 demonstrated that a structured physiotherapy program significantly improves walking speed, step length, and cadence in patients after lower limb amputation.

Thus, the obtained results emphasize the necessity of a multidisciplinary approach in the rehabilitation of patients with lower limb amputations, incorporating modern physiotherapeutic methods, massage, advanced technologies, and psychological support to achieve optimal functional outcomes and improve quality of life.

Conclusions

The proposed physical rehabilitation program for patients with lower limb amputations demonstrated effectiveness as a comprehensive approach that integrates pre- and post-prosthetic preparation, adaptation to the prosthesis, and gait skill development. The systematic implementation of physical exercises combined with physiotherapy, massage, and modern robotic technologies ensures improvements in muscle strength, balance, coordination, and functional mobility of patients.

The program's application in a clinical sample of 20 patients confirmed its ability to reduce rehabilitation duration, enhance mobility levels, and improve quality of life for individuals with foot, lower leg, or thigh amputations. Individualization of rehabilitation interventions, taking into account the level of amputation and the patient's functional capabilities, is a key factor in achieving optimal outcomes.

The combined use of psychological support and physical rehabilitation contributes to increased patient motivation and more effective adaptation to the prosthesis. Implementation of the proposed program can be recommended for broader clinical use to optimize the recovery process after lower limb amputation.

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PERSONALIZUOTOS REABILITACIJOS STRATEGIJOS PO APATINIŲ GALŪNIŲ AMPUTACIJOS:KLINIKINIAI IR FUNKCINIAI REZULTATAI

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SANTRAUKA

Darbo tikslas – įvertinti pacientų fizinės rehabilitacijos programos efektyvumą po apatinių galūnių amputacijos, atsižvelgiant į protezavimo ir judėjimo įgūdžių ugdymo ypatumus.

Buvo tiriama 20 pacientų, kuriems buvo atlikta transtibialinė amputacija. Reabilitacinę programą sudarė gydomoji fizinė kultūra, fizioterapija, masažas, robotizuotos technologijos ir psichologinė parama. Programos efektyvumas buvo vertinamas raumenų jėgos balanso, koordinacijos, funkcinio pajėgumo (paslankumo) ir gyvenimo kokybės rodikliais.

Tyrimo rezultatai. Realizuotoji programa davė teigiamus pacientų rehabilitacijos rezultatus. Pacientai pademonstravo likusiųjų galūnių raumenų jėgos padidėjimą, ėjimo žingsnio ilgis ir dažnis tapo labiau simetriški lyginant su pradiniais duomenimis. 6 min. trukmės ėjimo testo rezultatai padidėjo vidutiniškai nuo 240 iki 320 m, tai parodė padidėjusią ištvermę. Pusiausvyros rezultatai taip pat pagerėjo, vidutinis įvertinimas pagal *Berg Balance* skalę padidėjo nuo 42 iki 48 balų ir tai rodė padidėjusį judėjimo stabilumą. Funkcinio paslankumo rodikliai padidėjo visuose kojos amputacijos lygiuose, o didžiausias rodiklių progresas buvo pacientų su transtibialine amputacija. Svarbu pažymėti, kad struktūrizuotas rehabilitacijos protokolas sutrumpino rehabilitacijos trukmę

vidutiniškai 3 savaitėmis ir padėjo adaptuotis prie protezo. Psichologinė pagalba suvaidino svarbiausią vaidmenį įveikiant baimę kristi, padidino motyvaciją nuolat kasdienybėje naudotis protezu. Kombinuota multidisciplininė reabilitacijos programa padidino pacientų mobilumą, pagreitino reintegraciją į buitį, padidino kasdienį aktyvumą ir gerokai padidėjusią gyvenimo kokybę bei savivertę.

Išvados. Parengta ir įgyvendinta reabilitacijos programa buvo efektyvi optimizuojant atsistatymą po apatinių galūnių amputacijos. Jos taikymas klinikinėje praktikoje padidino funkcinius sužeistųjų rodiklius ir gyvenimo kokybę ir yra rekomenduotina plačiau taikyti reabilitacinėje praktikoje.

Raktažodžiai: apatinių galūnių amputacija, fizinės reabilitacijos programa, adaptacija prie protezo, ėjimo su protezais mokymas, gyvenimo kokybė.

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